Solid Oxide Electrolysis Cells - High pressure operation

Ebbesen, Sune Dalgaard

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Solid Oxide Electrolysis Cells

-High pressure operation

Sune D Ebbesen

Department of Energy Conversion and Storage

Danish Technical University, DTU

SYMPOSIUM

Water electrolysis and hydrogen as part of the future Renewable Energy System

Copenhagen, May 10-11 2012

The Solid Oxide Cell (SOC)
— Reversible, SOEC ↔ SOFC

- Electrolysis Cell (SOEC)

  $H_2O_{(cathode)} \rightarrow H_{2\ (cathode)} + ½\ O_{2\ (anode)}$

  $CO_{2(cathode)} \rightarrow CO_{\ (cathode)} + ½\ O_{2\ (anode)}$

- Fuel Cell (SOFC)

  $H_{2\ (anode)} + ½\ O_{2\ (cathode)} \rightarrow H_2O_{\ (anode)}$

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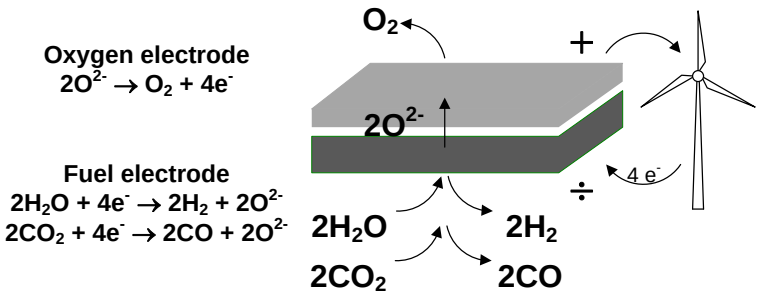

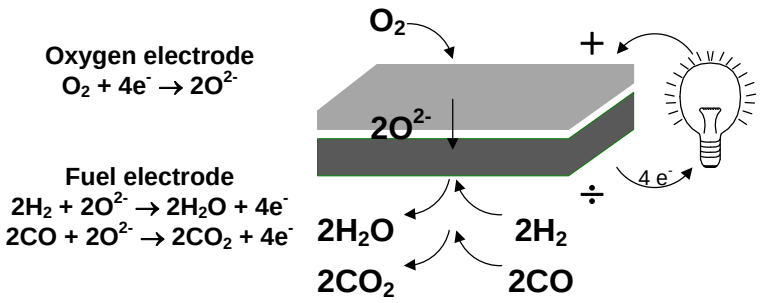

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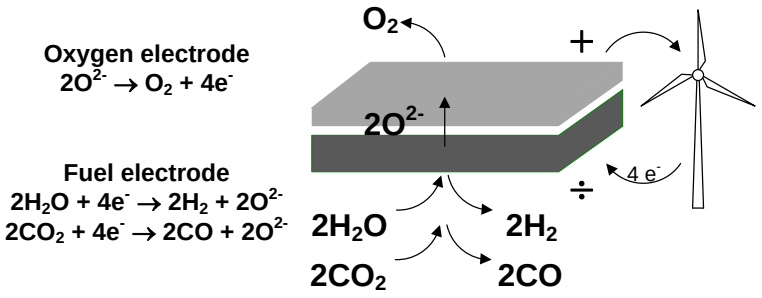
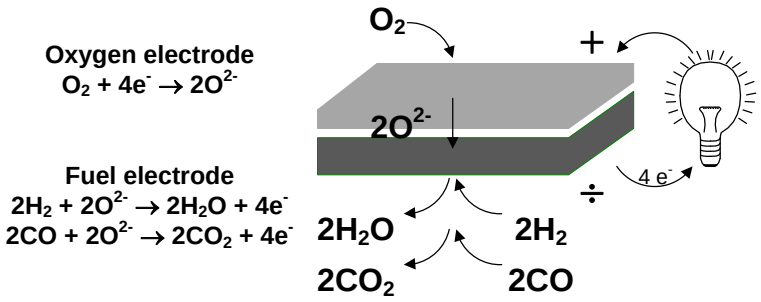




One major advantage of SOECs is the possibility to reduce CO_2 to CO

Solid Oxide Electrolysis Cells

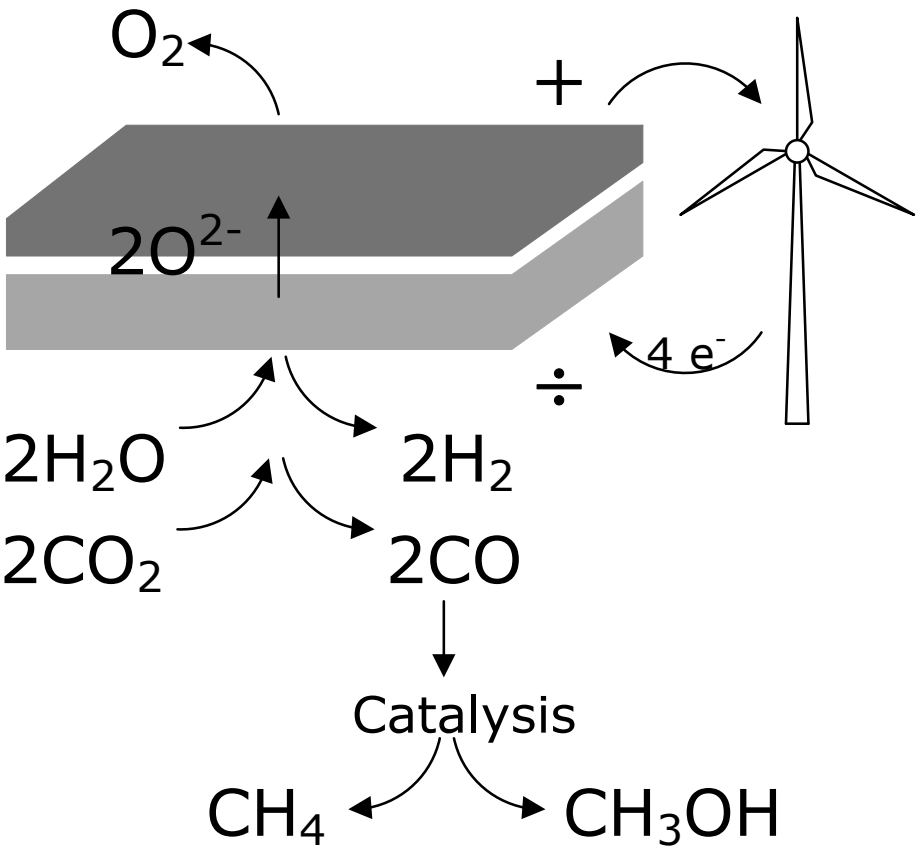
Oxygen electrode

$2O^{2-} \rightarrow O_2 + 4e^-$

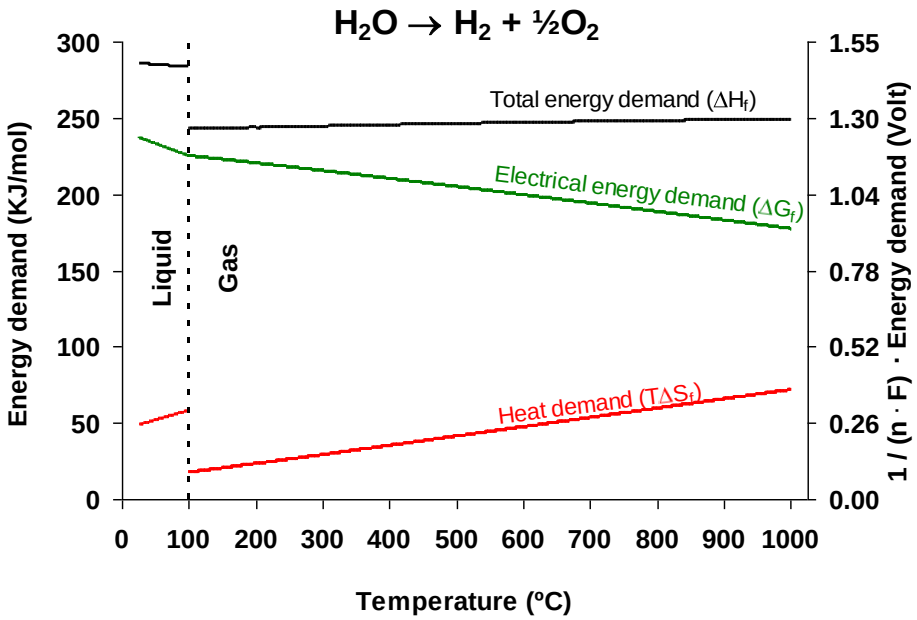
Fuel electrode

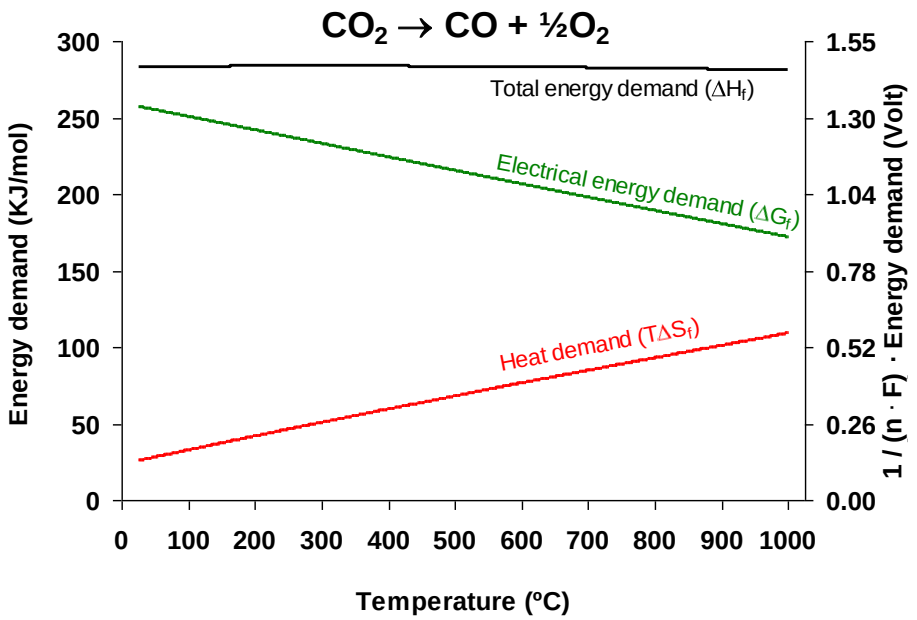
$2H_2O + 4e^- \rightarrow 2H_2 + 2O^{2-}$

$2CO_2 + 4e^- \rightarrow 2CO + 2O^{2-}$

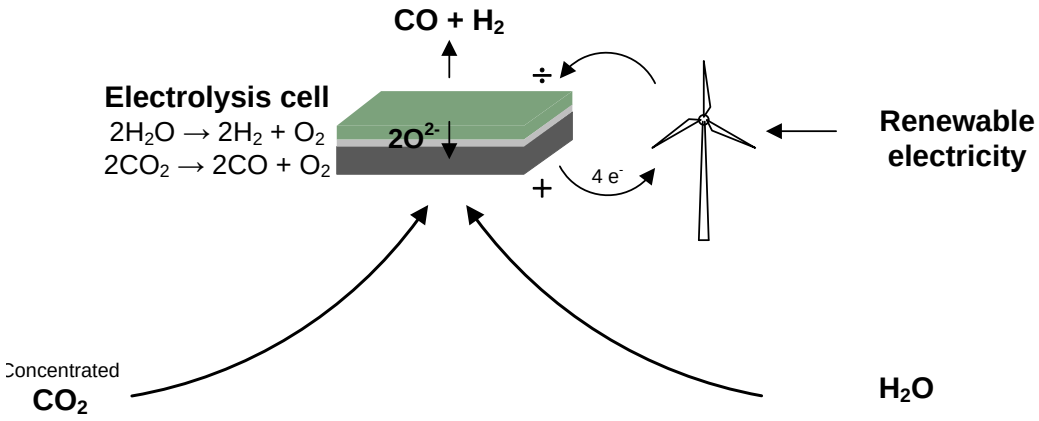


Solid Oxide Electrolysis Cells
— Operation at high temperature

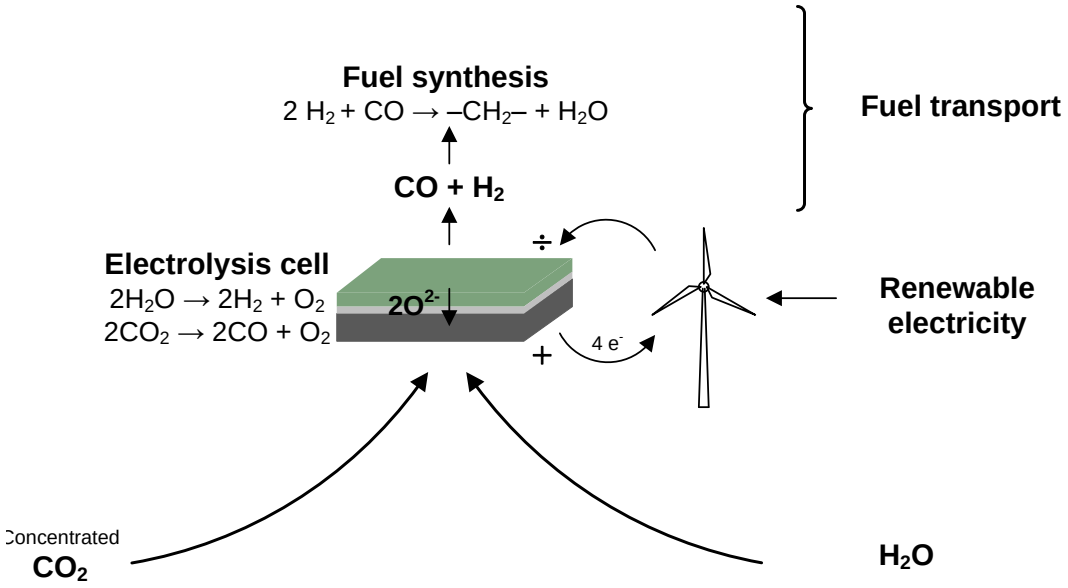




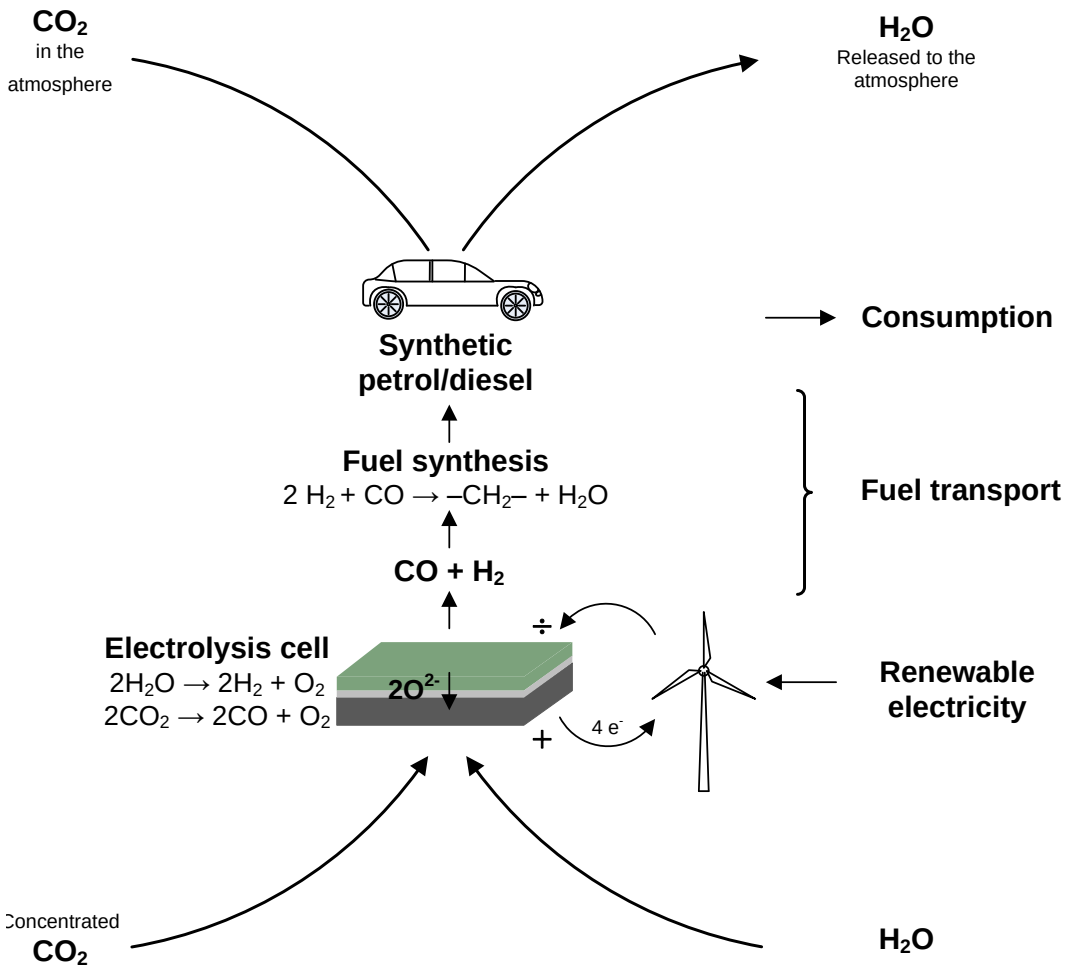
Vision


CO + H2
Electrolysis cell
2H2O → 2H2 + O2
2CO2 → 2CO + O2
2O2-
÷
+
4 e-
Renewable electricity
Concentrated CO2
H2O

Vision

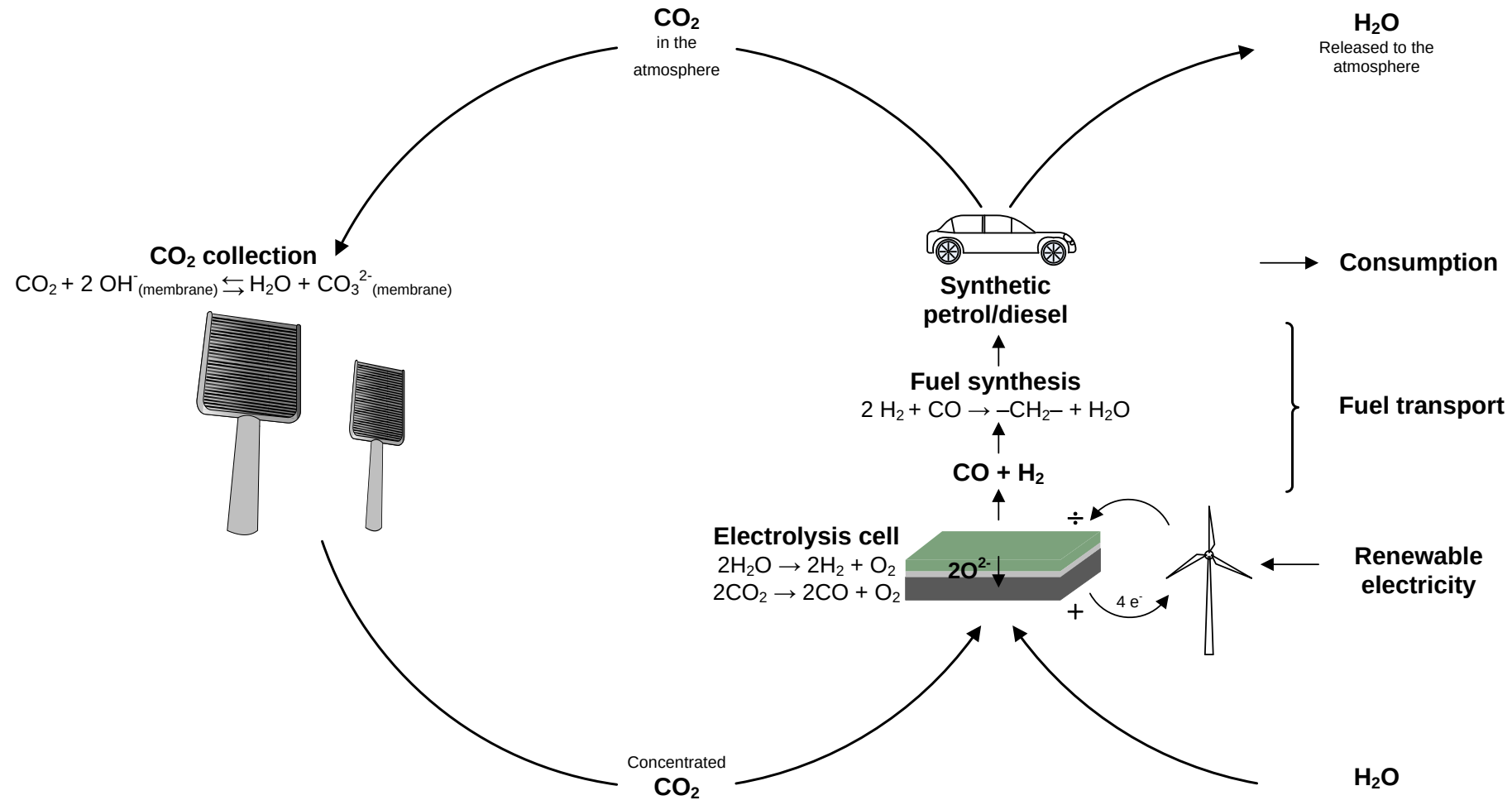

Fuel synthesis
2 H2 + CO → –CH2– + H2O
CO + H2
Fuel transport
Electrolysis cell
2H2O → 2H2 + O2
2CO2 → 2CO + O2
÷
2O2-
+
4 e-
Renewable electricity
Concentrated CO2
H2O

Vision


CO_2
in the
atmosphere
H_2O
Released to the
atmosphere
Consumption
Synthetic
petrol/diesel
Fuel synthesis
2 H_2 + CO → –CH_2– + H_2O
Fuel transport
CO + H_2
÷
Electrolysis cell
$2H_2O \rightarrow 2H_2 + O_2$
$2CO_2 \rightarrow 2CO + O_2$
$2O^{2-}$
4 e^-
+
Renewable
electricity
Concentrated
CO_2
H_2O

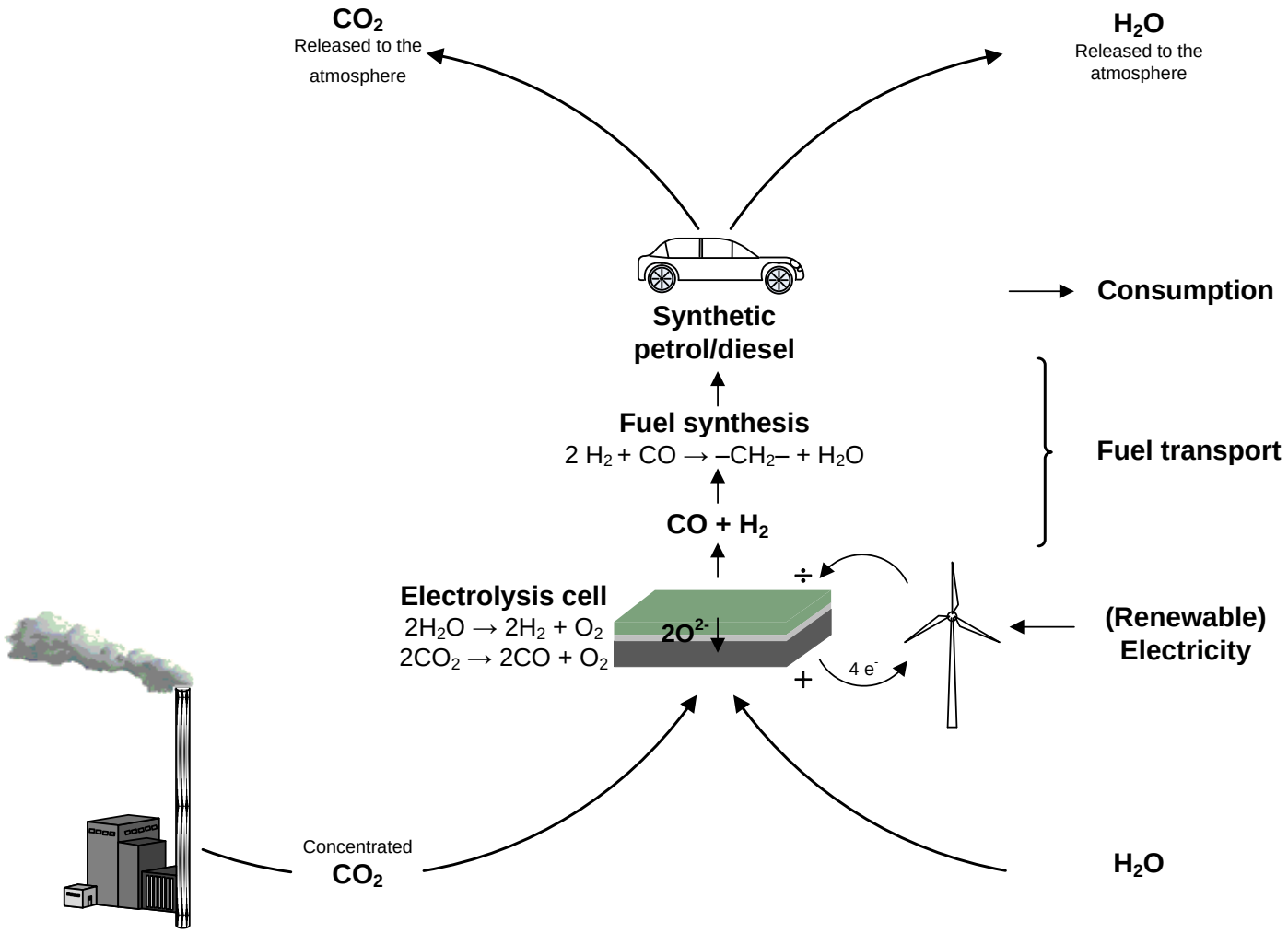
Vision

— Collection of CO_2 from the atmosphere



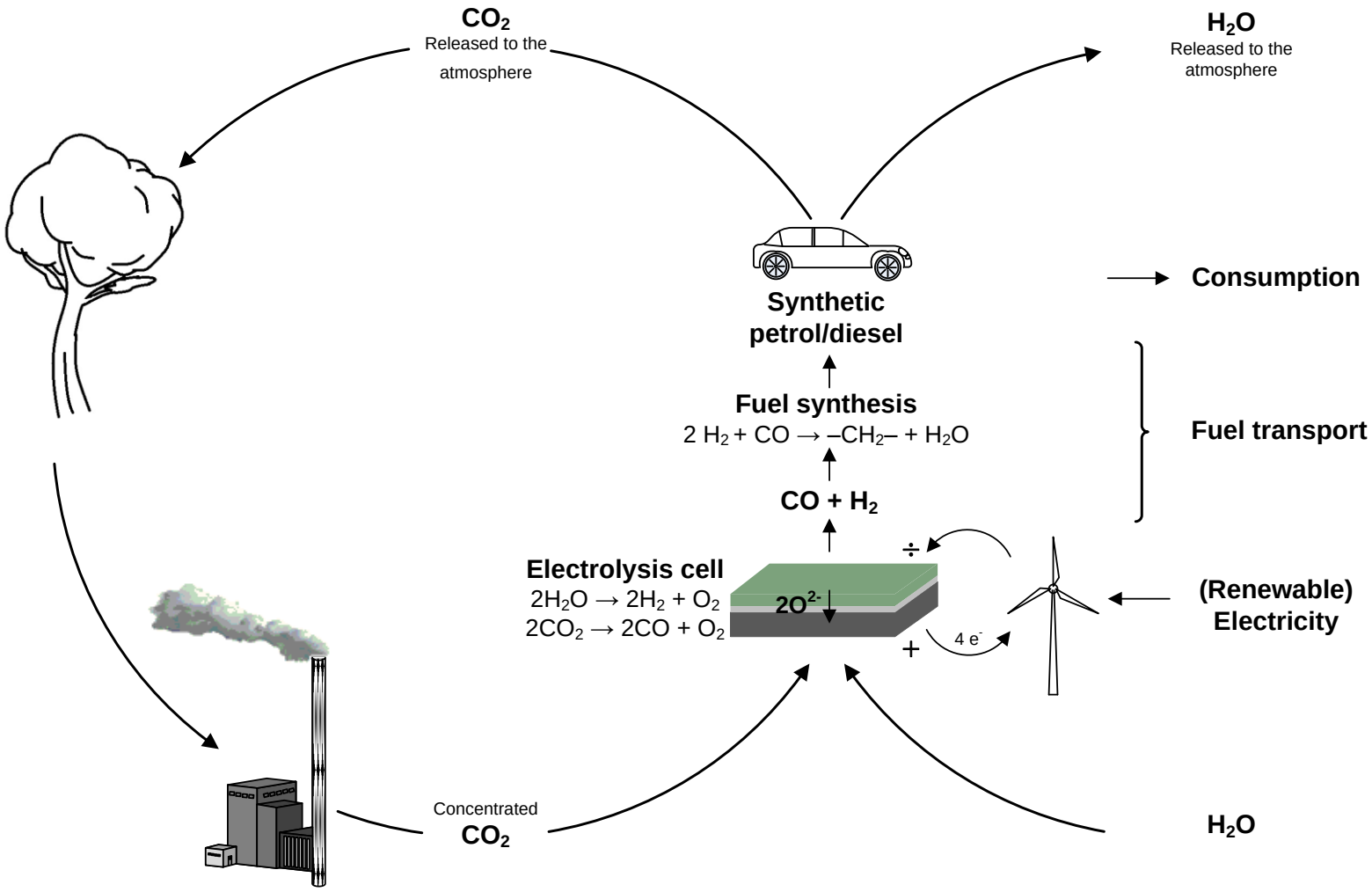
Vision

— Collection of CO_2 from industries



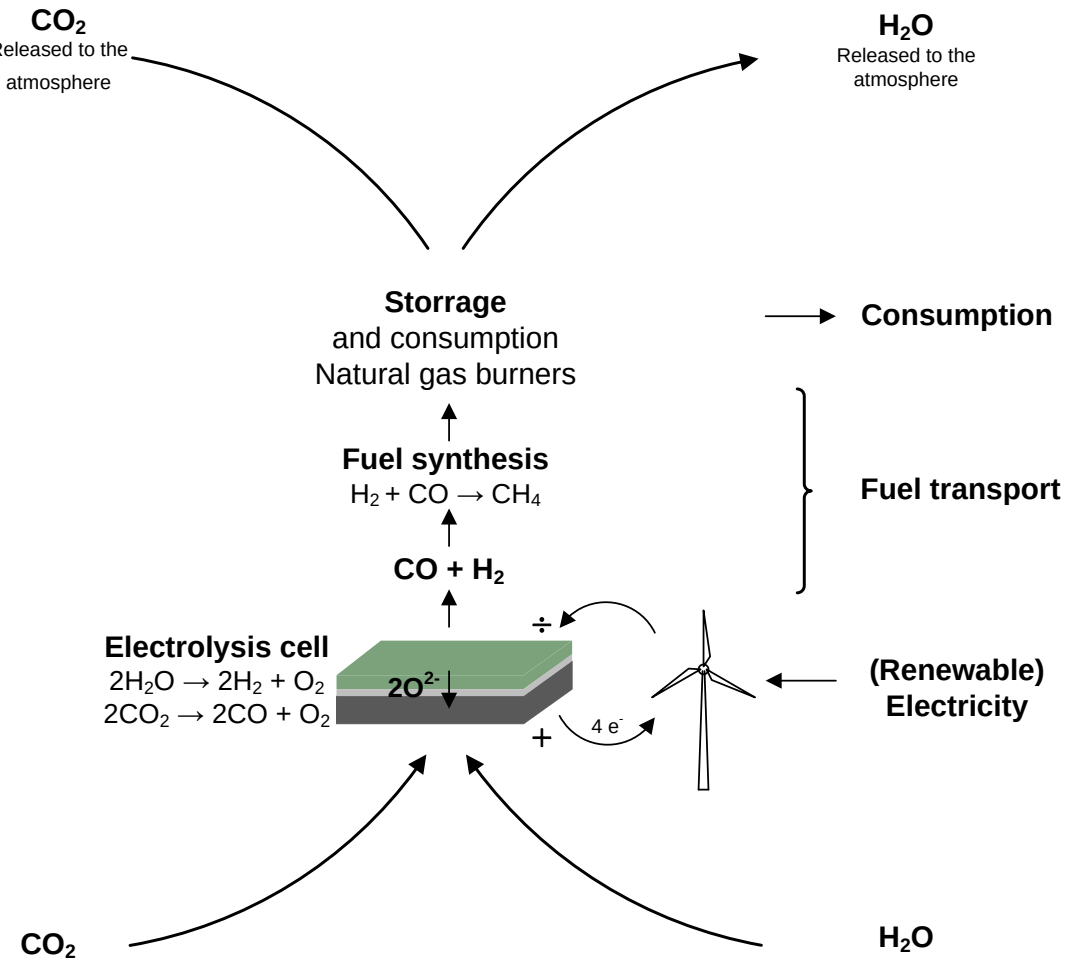
Vision

— Collection of CO_2 from power plants



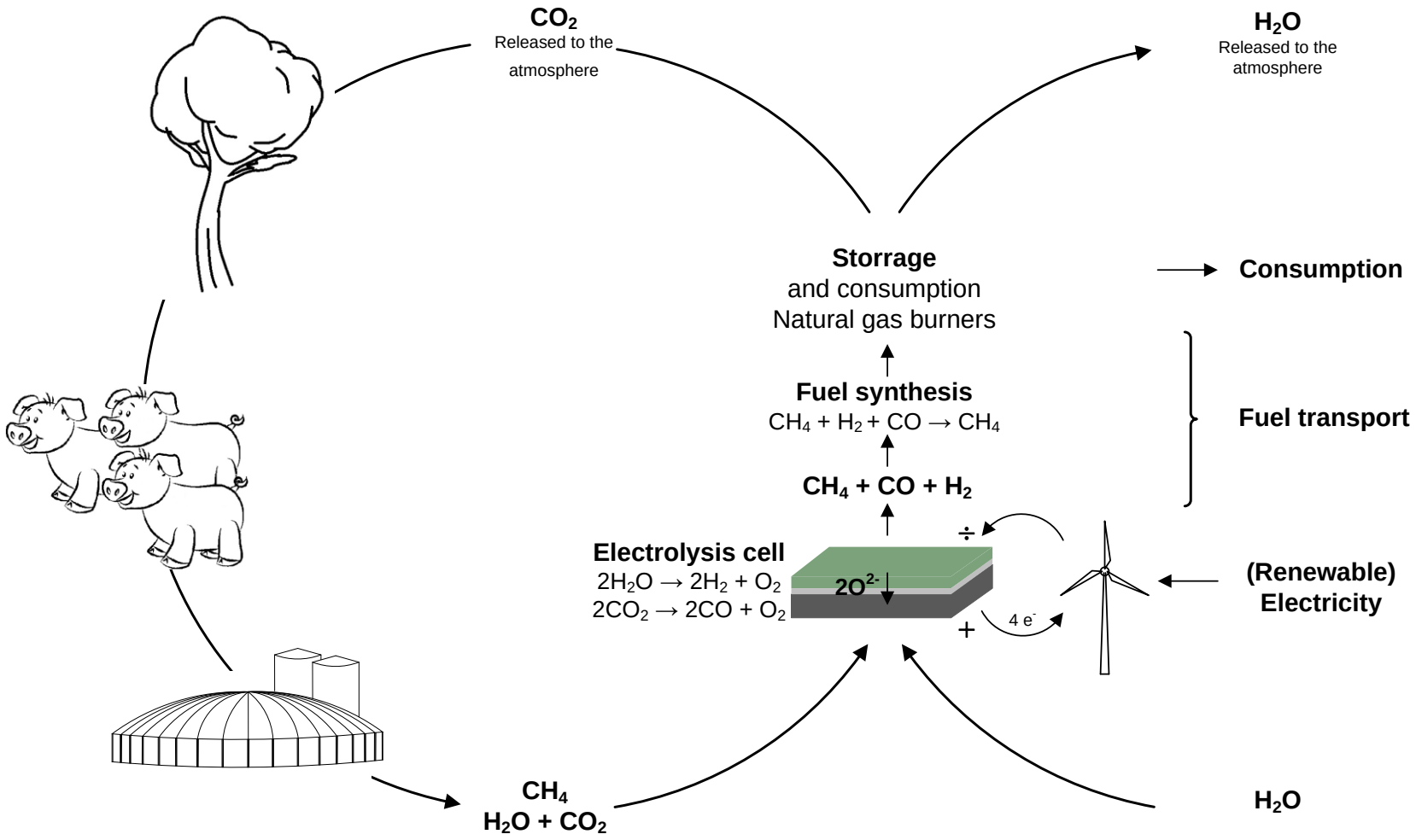
Vision

— Storing renewable electricity via Natural Gas



Vision

— Biogas upgrading



Vision

- Production of synthetic fuels from renewable electricity (wind) and:
  - CO_2 from the atmosphere
  - CO_2 from the industry
  - CO_2 from biomass fired power plants
- Storage of renewable electricity via synthetic fuels and the natural gas grid
- Biogas upgrading

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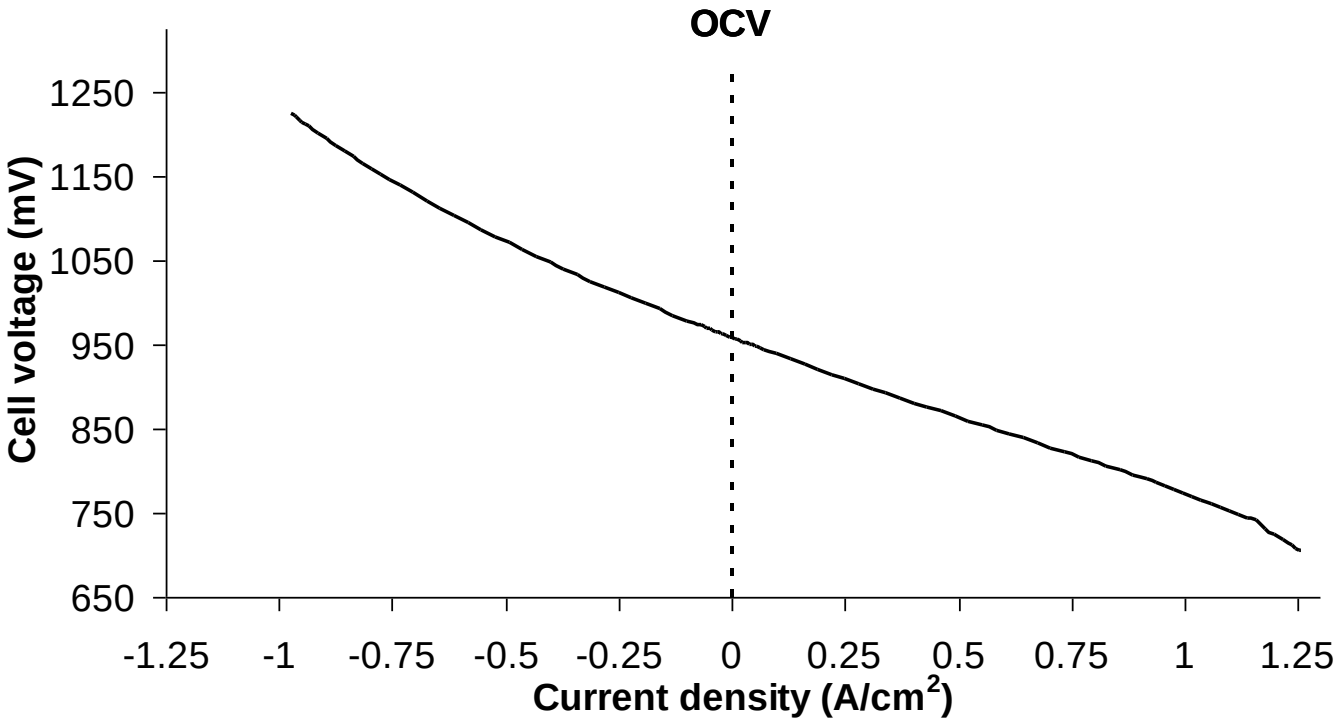
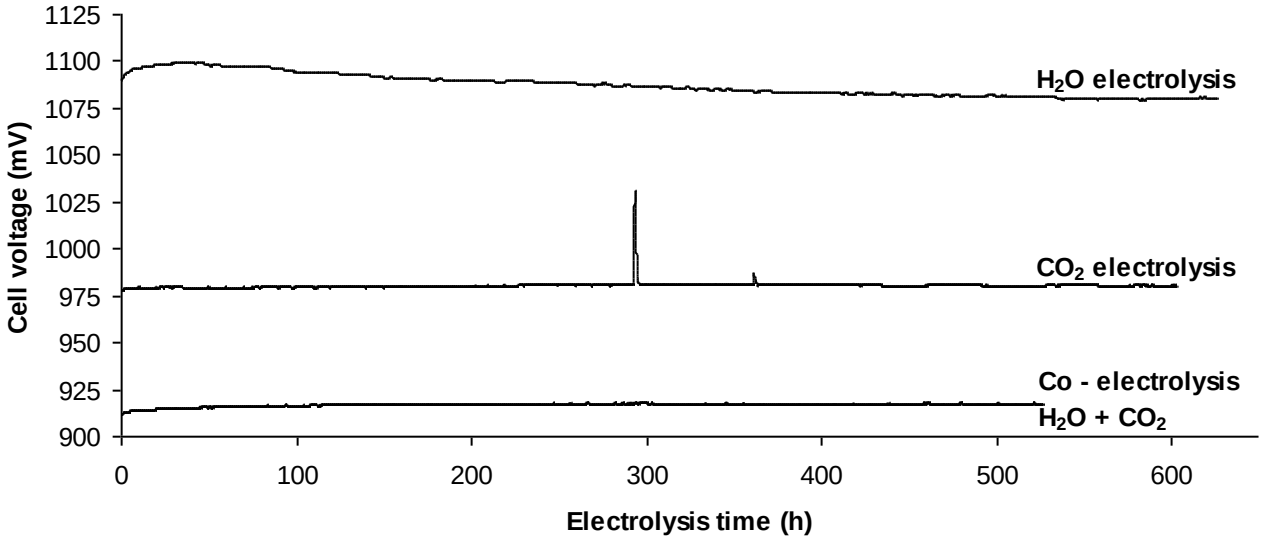


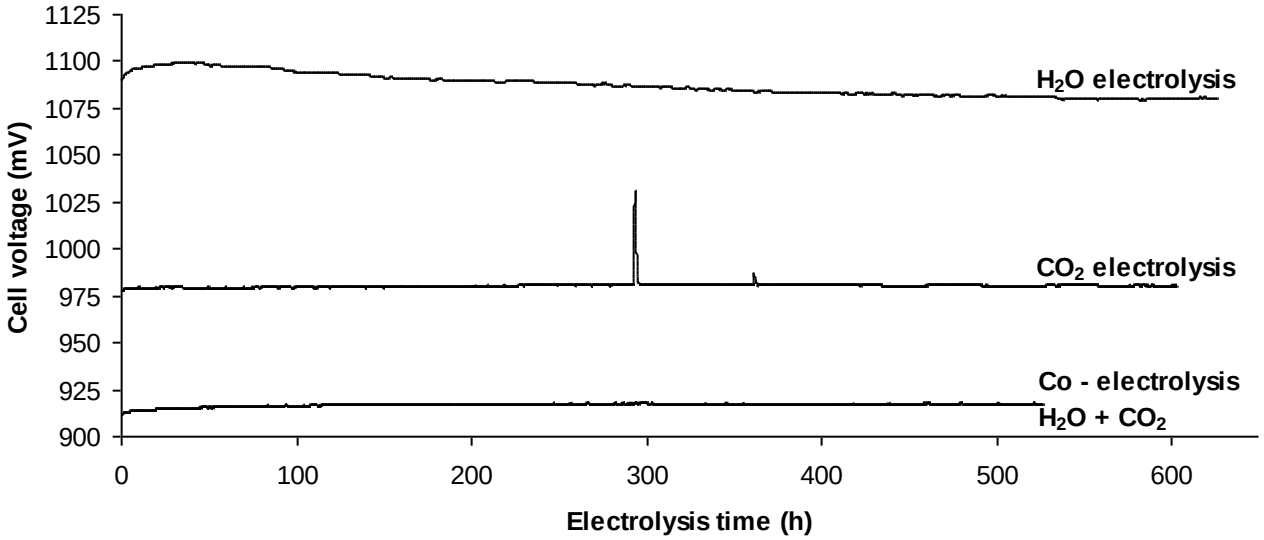
Conditions: 850ºC, 50% H_2O – 50% H_2

Electrolysis durability at low current density
—Cleaned inlet gases and improved setup



Conditions:
Steam electrolysis: 850ºC, -0,50 A/cm^2, 50% H_2O – 50% H_2
CO_2 electrolysis: 850ºC, -0,25 A/cm^2, 70% CO_2 – 30% CO
Co-electrolysis: 850ºC, -0,25 A/cm^2, 45% CO_2 – 45% H_2O – 10% H_2

Electrolysis durability at low current density
—Cleaned inlet gases and improved setup

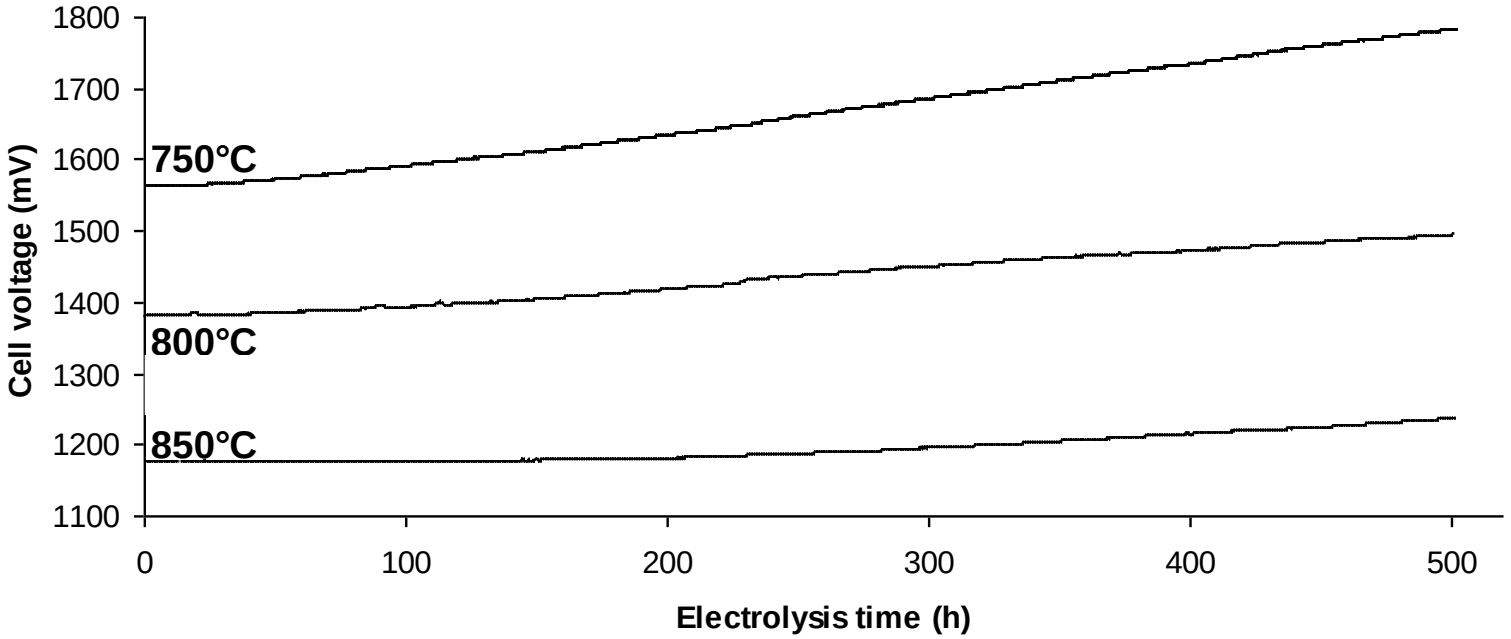


No degradation or even activation with clean inlet gases and a setup without contaminants

Conditions:
Steam electrolysis: 850ºC, -0,50 A/cm^2, 50% H_2O – 50% H_2
CO_2 electrolysis: 850ºC, -0,25 A/cm^2, 70% CO_2 – 30% CO
Co-electrolysis: 850ºC, -0,25 A/cm^2, 45% CO_2 – 45% H_2O – 10% H_2

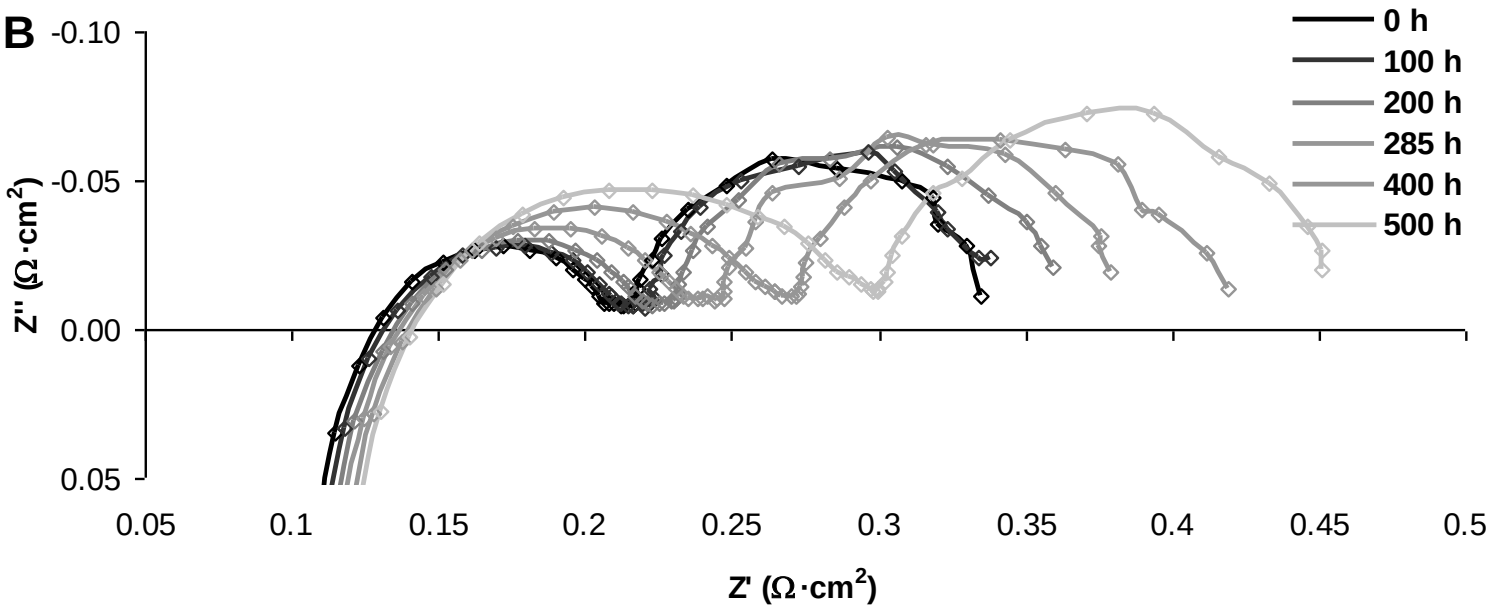
Electrolysis durability at high current density

Electrolysis durability at high current density
—Standard Ni-YSZ based cells with LSM O_2 electrode



Conditions: -1,0 A/cm^2, 45% CO_2 – 45% H_2O – 10% H_2

Electrolysis durability at high current density — Today



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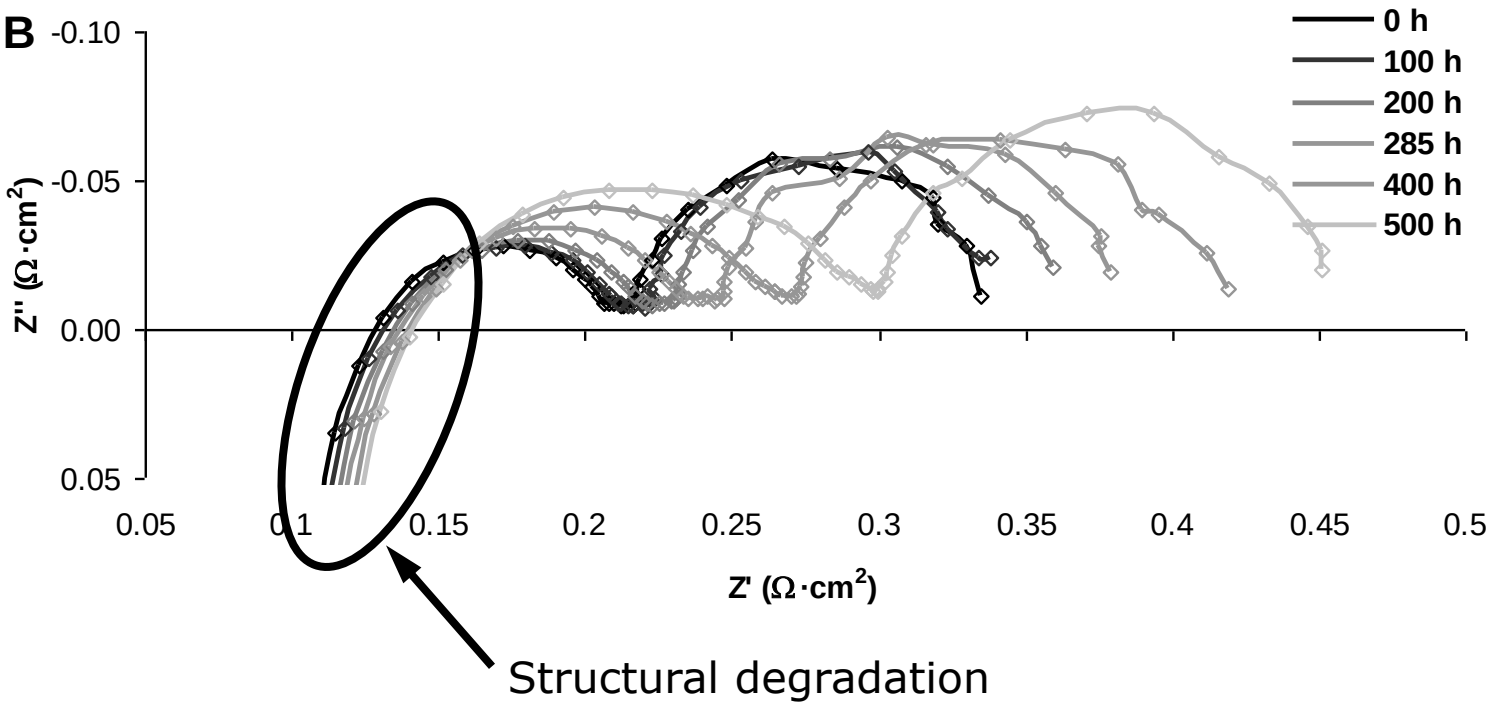

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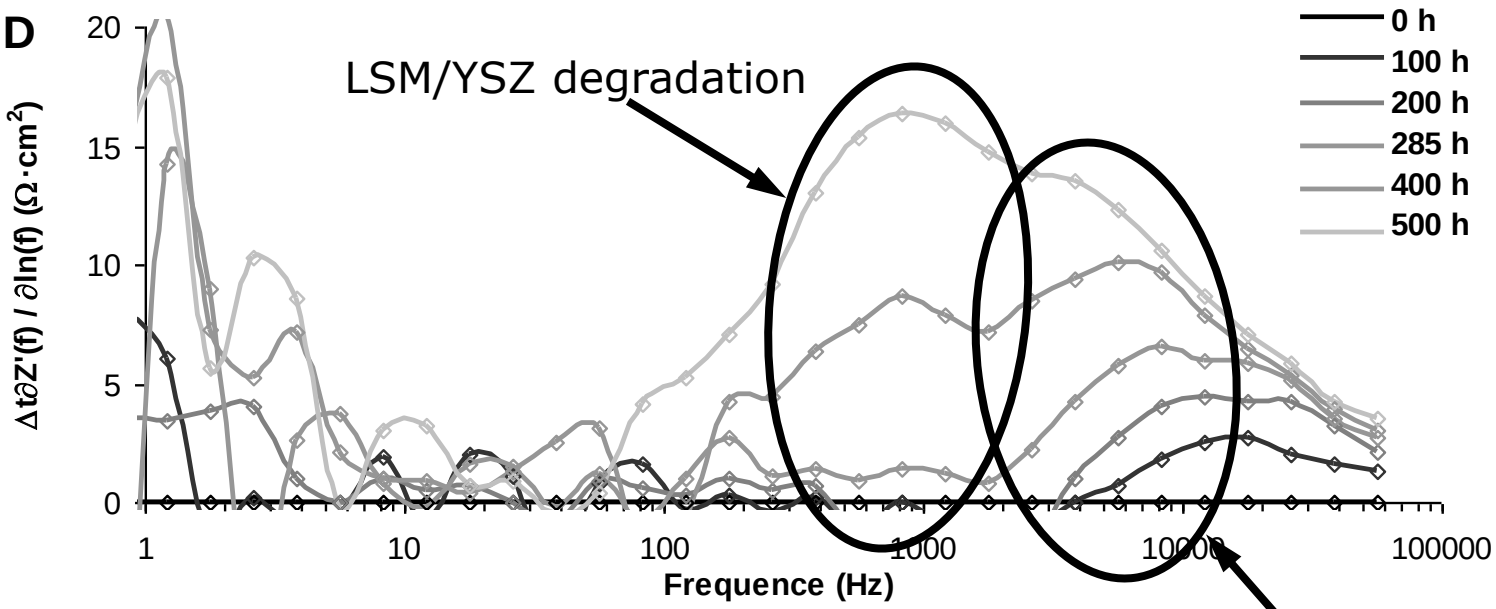

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Electrolysis durability at high current density — Today

Ni/YSZ electrode

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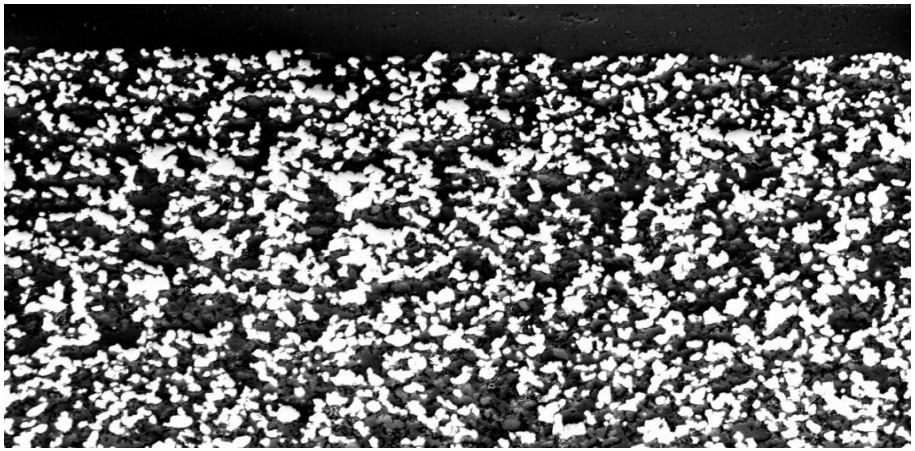
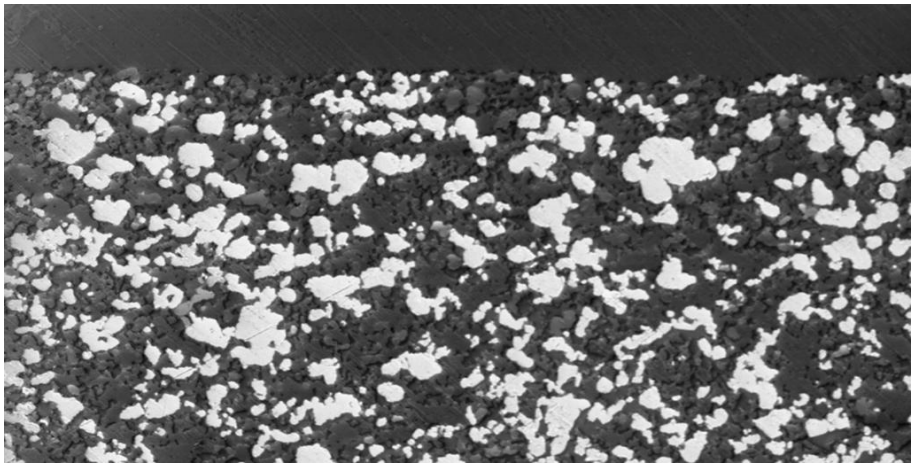
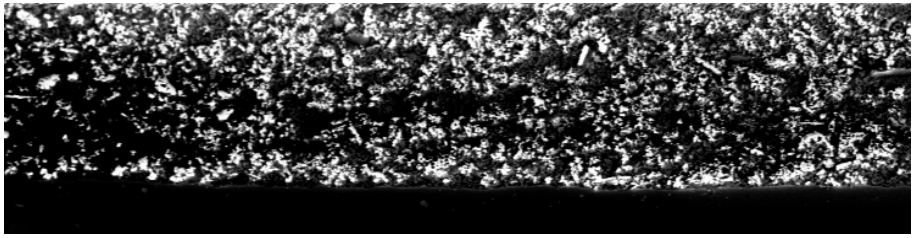


Tested cell



LSM/YSZ electrode

Reference



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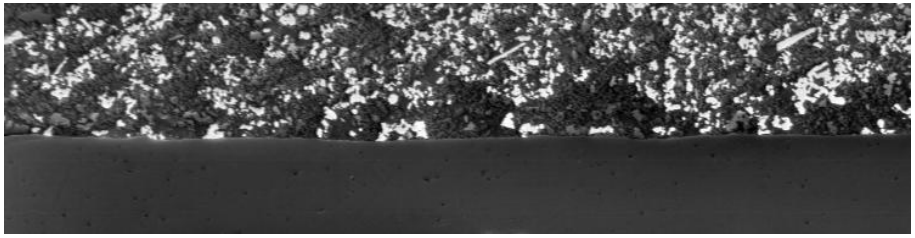

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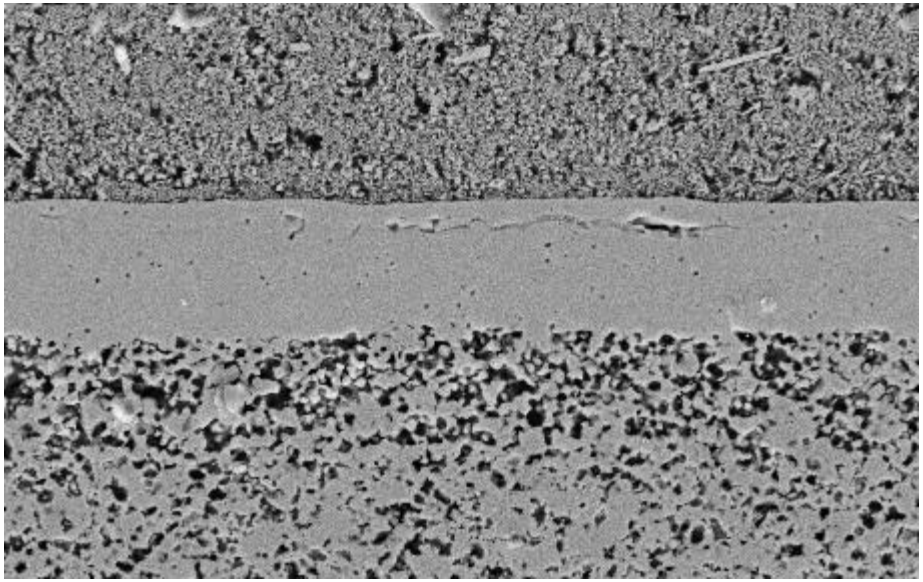

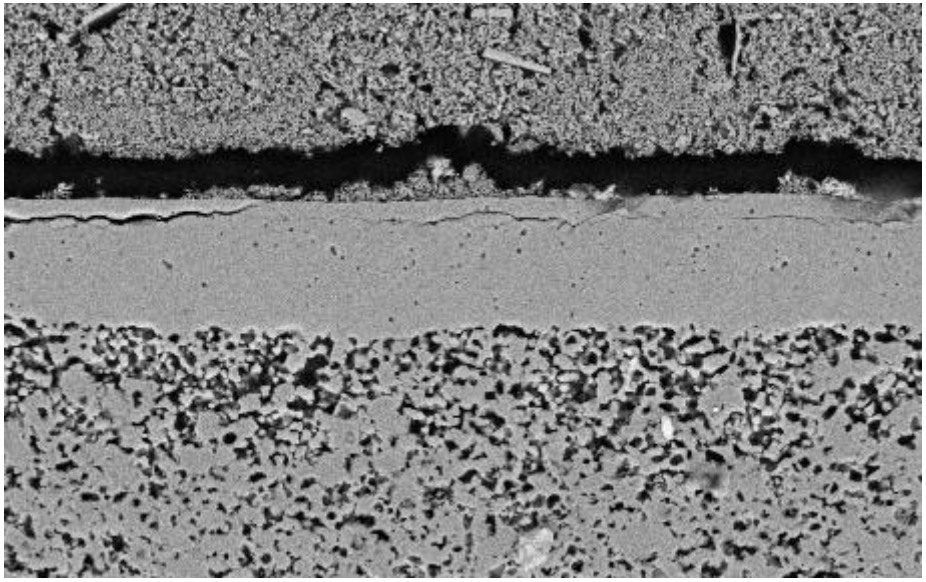

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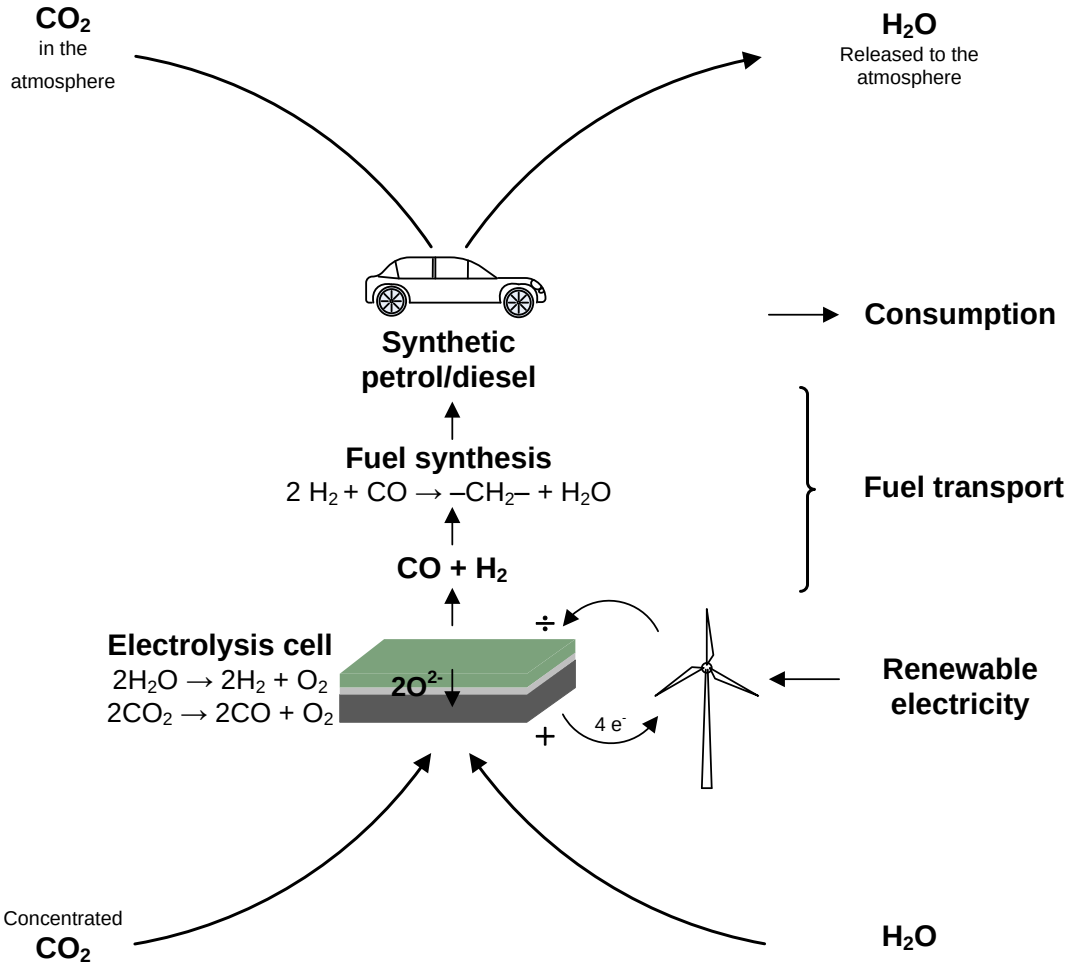
Vision
— Synthesis at increased pressure

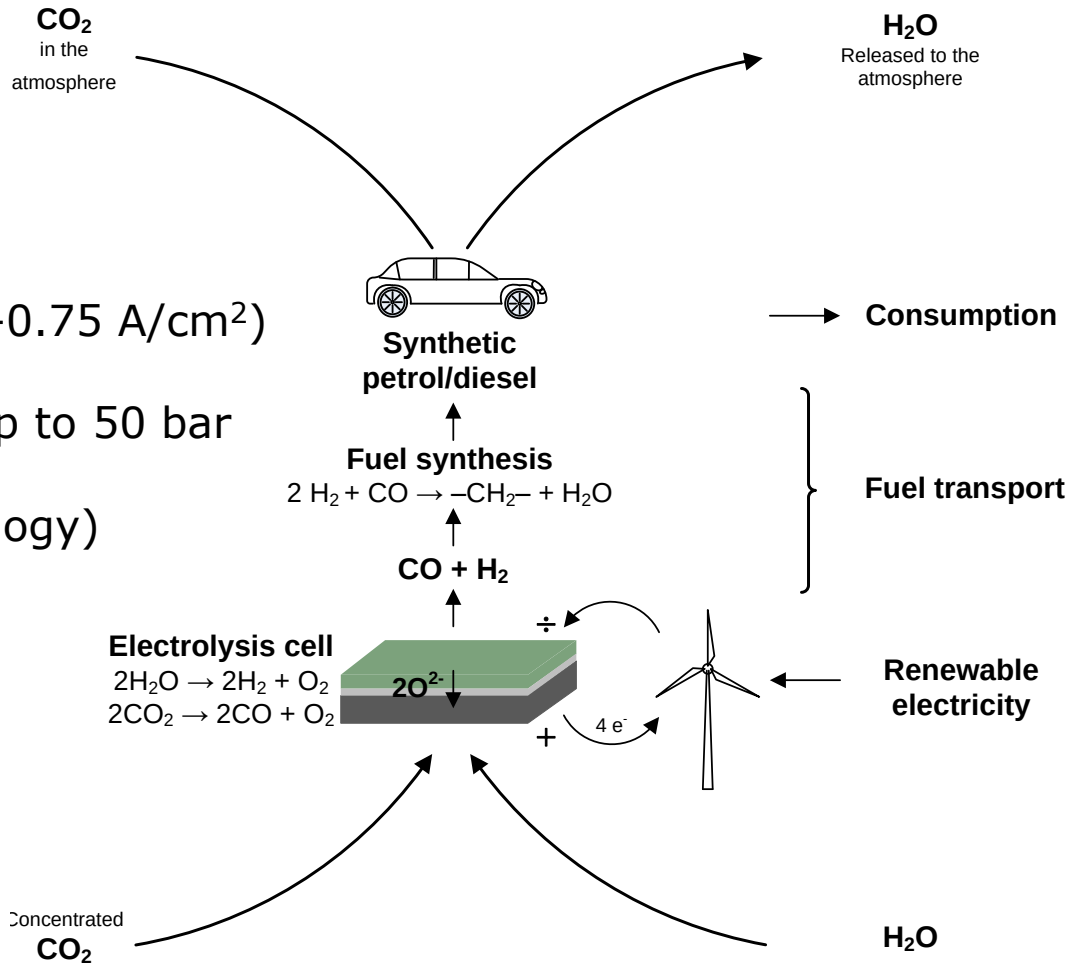


Vision
— Synthesis at increased pressure

1) Durable stacks (proven up to -0.75 A/cm^2)

2) Stacks operated at pressure up to 50 bar

3) Fuel synthesis (proven technology)



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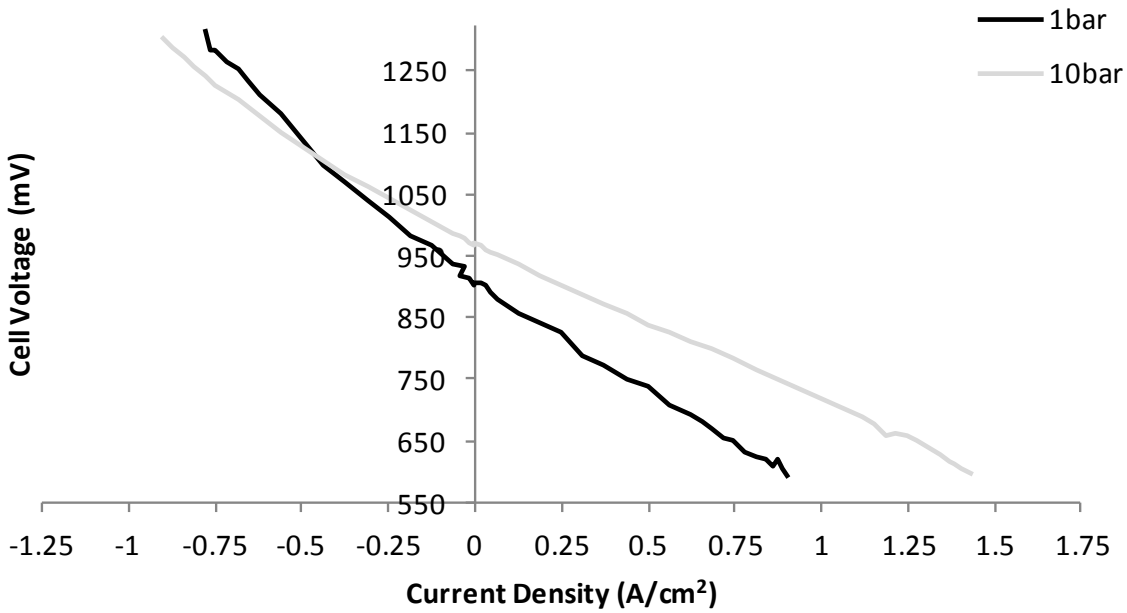

Summary

- The Solid Oxide Cells are fully reversible

  Fuel cell operation $\longleftrightarrow$ Electrolysis operation

- Degradation is more severe in electrolysis mode compared to fuel cell mode

- Degradation at mild conditions is related to impurities

  This degradation can be avoided by cleaning for impurities

- At harsh conditions structural changes occur in the cells

  Need cells with lower polarisation $\rightarrow$ lower degradation

- Cells can be operated safely at current densities up to -0.75 A/cm^2 at 850ºC

- Operation at high pressure advantageous for system integration

- Solid Oxide Electrolysis cells may contribute to storage of renewable electricity

Acknowledgement

- The Danish National Advanced Technology Foundation's advanced technology platform
  "Development of 2nd generation bioethanol process and technology"

- Danish Council for Strategic Research, via the Strategic Electrochemistry Research Center

- European Commission via the project "Hi2H2"

- European Commission via the project "RelHy"

- EUDP via the project "Green Natural Gas"

- Danish PSO via the project "PlanSOEC"

- Danish PSO via the project "Durable solid oxide electrolysis cells and stacks"

- DTU Energy Conversion (Former Risø DTU) via the project SOECcell

- Topsoe Fuel Cell A/S (TOFC)